Ocean Dynamics

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LONG-TERM GOALS

To gain a more complete understanding of ocean dynamical processes, particularly at fine-scale, through intercomparison of high, mid- and low-latitude observations, both near the sea surface, in the main thermocline, and near the sea floor.

OBJECTIVES

To identify the phenomena involved in the cascade of energy from mesoscales to turbulent scales. To quantify the relationship between fine-scale background conditions and the occurrence of microscale breaking.

APPROACH

Progress is effected through a steady-state cycle of instrument development, field observation and data analysis. The primary instruments employed include Doppler sonar and profiling CTD's. Generically, our instruments produce information which is quasi-continuous in space and time. Measurements typically span two decades in the wavenumber domain. This broad band space-time coverage enables the investigation of multi-scale interactions.

WORK COMPLETED

A re-analysis of the effect of internal solitary waves on ocean acoustic backscattering is being completed. Recent interest has focused on the role of coastal solitary waves on the refraction of sound in shallow water propagation experiments. It is now becoming apparent that there is often a significant backscattering signal associated with solitary waves as well, presumably from the production of turbulent index of the refraction fluctuations induced by soliton passage. Such backscattering signals have been seen in deep water (Pinkel 1999, Figures 1,2) as well as coastal (Moum, in-press) solitons. The turbulence generation mechanism associated with soliton passage is unclear. Moum (personal communication) feels that the shallow water solitons induce sufficient shear on a “steppy” density gradient to caurse instability. Pinkel (1999) feels that strong pre-existing background shears are required in order that deep water solitons can “trigger” overturning.

The relationship between turbulence and acoustic scattering has been known since WWII, when submarine skippers would intentionally side-slip (yaw) their vessels, to introducing turbulent “ghost” targets to confuse enemy sonar. The scattering process was subsequently studied in detail by Tatarskii,

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14. ABSTRACT

To gain a more complete understanding of ocean dynamical processes, particularly at fine-scale, through intercomparison of high, mid- and low-latitude observations, both near the sea surface, in the main thermocline, and near the sea floor.

15. SUBJECT TERMS

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initially with atmospheric applications in mind, by Middleton, by Goodman, 1990, and recently by Seim, Gregg and Miyamoto 1995).

Initially (eg Proni 1975), it was hoped that observed backscattering levels could be used to estimate dissipation directly, as if the turbulent process was in the steady state envisioned by Batchelor (1958) when deriving theoretical spectral forms for the power spectra of temperature and salinity fluctuations. We believe that this is an incorrect interpretation.

It is now appreciated that typically 1-2% of the water column is actively overturning (perhaps more when solitons pass). The isolated mixing patches remain actively turbulent for several buoyancy periods following generation. However the temperature and salinity fine structures created by the mixing (at Bragg scales of 1-3 cm) can persist for tens of minutes (temperature) to hours (salinity). It is thus more appropriate to model the scattering as if from a non-conservative "acoustic dye", which, following initial creation, is dispersed passively by the background shears as it slowly diffuses.

Such a model suggests that observed scattering levels are dependent on the number of actual turbulent patches produced per unit space-time, the maximal volume of each patch and the intensity of index of refraction fluctuations at "the" time when active turbulence ceases. Thus the quantity of "dye" production per unit time is balanced by molecular dissipation.

In Moum's coastal observations, where the water is temperature-stratified, the observed backscattering signals vanish in ~10 minutes. In Pinkel's salt stratified equatorial observations, the intensity anomalies persist for hours. This discrepancy is consistent with the relative molecular diffusivities of heat and salt and serves to illustrate that dissipation is only one of the key factors influencing acoustic scattering.

Figure 1. A deep water internal solitary wave seen in the western equatorial Pacific (2°S, 156°E) using a 160 kHz Doppler sonar with 4 m depth resolution. The general south-western flow of the mixed layer (0—80 m) is interrupted by the passage of the leading wave crest at 10:30 hours. Following passage of the third crest, the upper ocean has been brought to a halt. The ship from which the observations were made was displaced over 1km north-eastward by the passage of the wave train.

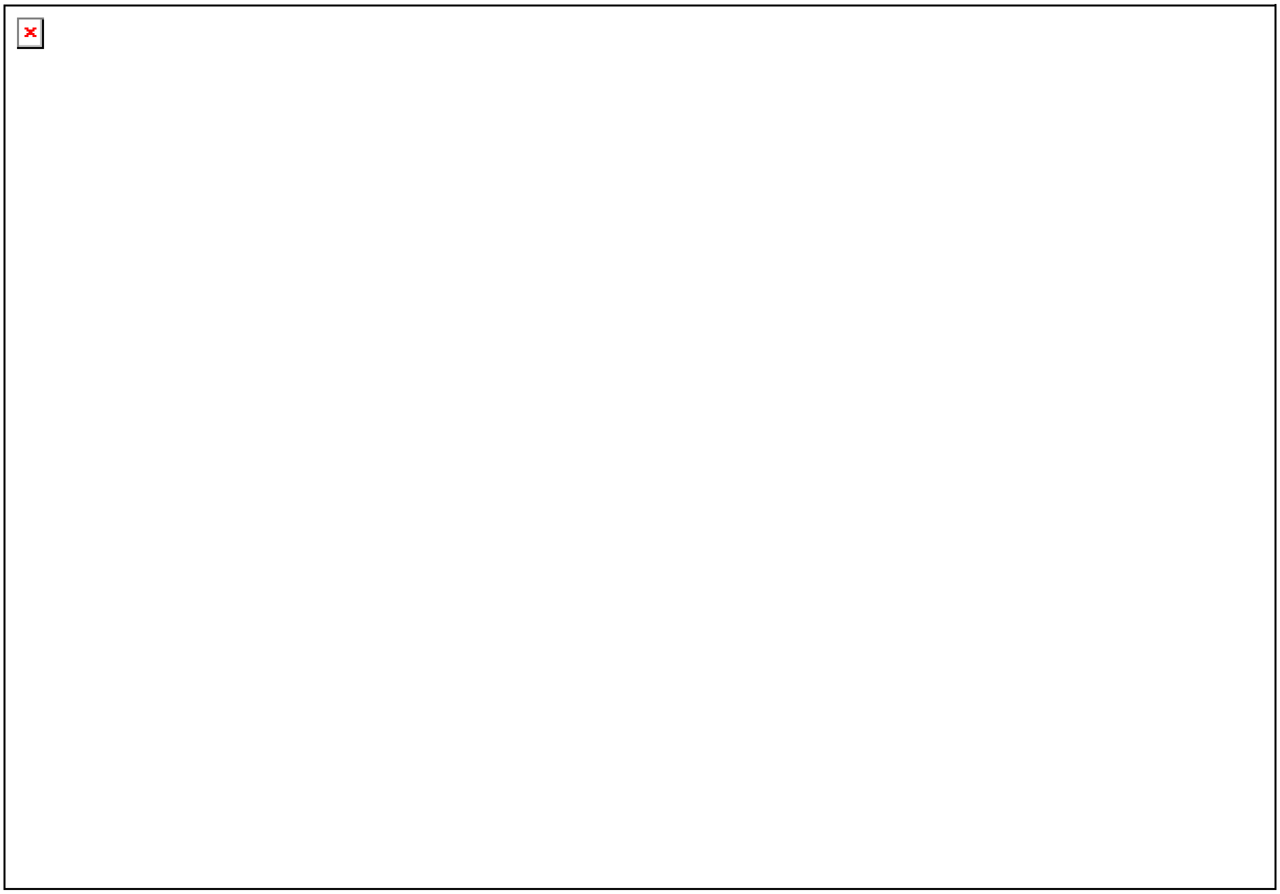

Figure 2. The acoustic scattering strength field during the passage of the soliton shown in Figure 1. Colors indicate echo intensity in arbitrary units, corrected for attenuation and spreading loss. The black lines represent estimates of flow streamlines calculated from the observed velocity field. Blue rectangles indicate location where large- scale (>2m) overturns are observed in the density profiles obtained by a CTD. Note the increase in scattering early in the record due to the nocturnal arrival of migrating zooplankton in the upper ocean. Scattering levels subsequently increase with the passage of each crest. The overturning seen in at 40 m generates relatively little backscattering. The temperature and salinity is fairly uniform at this depth. Overturning does not produce large fluctuations in index of refraction. Further down, significant scattering increases are seen. Most of the scattering results from distant, "upstream" overturns, with the index of refraction fluctuations being advected/dispersed to the observation site.

RESULTS

This model, along with direct acoustic and in-situ field observation can potentially help to understand the processes by which solitons dissipate energy. A proper understanding of the "acoustic dye" effect will lead toward an increased use of acoustics in the study of ocean dissipation and dispersion. Also, the parameters governing the generation and evolution of man-made acoustic "ghosts" can be determined from these soliton studies.

IMPACT/APPLICATIONS

Preparations are under way for a 1995 cruise on the R/V Revelle to the S. China Sea to study the deep-water solitons generated in the Luzon Strait. These are reputed to be the largest solitons ever observed. The study of the interaction of the waves and their background and the documentation of observed dissipation and scattering should greatly advance our understanding.

RELATED PROJECTS

The ONR ASIAEX Program.

PUBLICATIONS

Alford, M.H., R. Pinkel, 2000: Observations of overturning in the thermocline: The context of ocean mixing. J. Phys. Oceanogr., 30, 805-832

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